Section 2. -- Effects of Minimum Flows on Other Organisms

As applied here, the VEC approach assumes that MFL flows based on *Vallisneria americana* will not harm, and may benefit, other estuarine organisms. The scientific peer review panel concluded that this assumption required additional documentation. The panel further recommended that the response of organisms in the lower estuary to the freshwater inflows and salinity associated with the MFL should be determined (Edwards et al 2000). In this section we summarize results of several studies that address this issue.

Oysters

The South Florida Water Management District (SFWMD) has conducted considerable research on SAV (Chamberlain and Doering 1997; Chamberlain and Doering 1998; Doering et al. 1999; Kraemer et al. 1999; Doering and Chamberlain 2000; Doering et al. 2002). However, studies of other valued ecosystem components, such as oyster reefs, that occur in the higher salinity waters of the lower Caloosahatchee Estuary are presently lacking. Such studies are clearly necessary. In response to this need, the District funded Drs. Aswani Volety and Gregory Tolley (Florida Gulf Coast University) to investigate oyster ecology in the Caloosahatchee Estuary. Results of their studies are summarized here and in **Appendix B**.

Investigations of oyster reef distribution indicate that these are prevalent in San Carlos Bay and Matlacha Pass, in areas that normally experience marine salinities. Oysters are not present as reefs above Shell Point on the south side of the estuary and Cattle Dock on the north side (**Figure 2-1**). Clumps of oysters may be found as far upstream (east) as the Cape Coral Bridge. As in other systems, oyster reefs form critical habitat for fish and a variety of invertebrates. To date, nine species of crabs and shrimp and 17 species of fish have been identified from lift net samples.

One of the major factors that can limit the distribution and life span of the oyster is infection with the protozoan parasite, *Perkinsus marinus*. *Perkinsus marinus* has devastated oyster populations in the Atlantic (Burreson and Ragone-Calvo 1996), where it is currently the primary pathogen of oysters, and in the Gulf of Mexico (Soniat 1996). Andrews (1988) estimated that *P. marinus* can kill up to 80% of the oysters in a bed. The

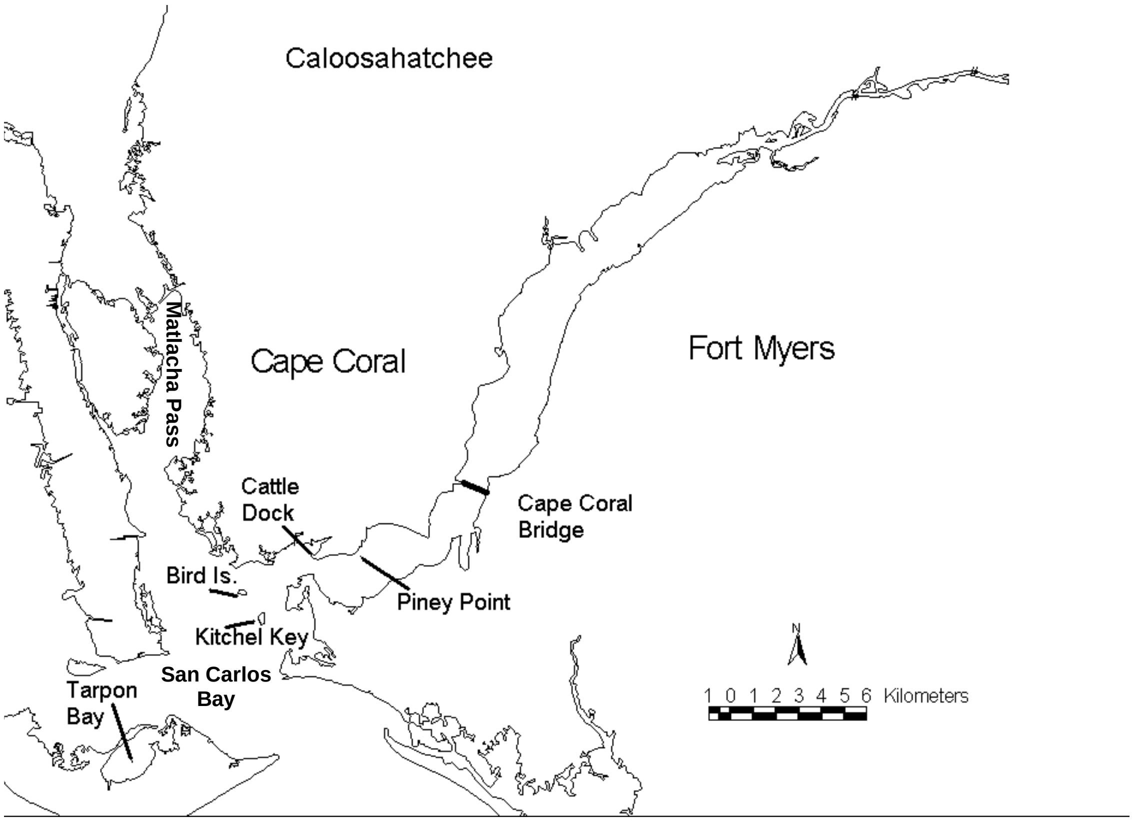

Figure 2-1. Location of oyster sampling sites in the Caloosahatchee River (Cattle Dock, Piney Point), San Carlos Bay (Bird Is., Kitchel Key) and Tarpon Bay

distribution and prevalence of *P. marinus* is influenced by temperature and salinity with higher values favoring the disease organism (Burreson and Ragone-Calvo 1996, Soniat 1996, Chu and Volety 1997). Field and laboratory studies indicate that *P. marinus* exerts severe pressure on growth, survival, and energy reserves of oysters, thereby limiting reproduction and recruitment.

Volety concluded that the antagonistic effects of temperature and salinity keep *P. marinus* infection in oysters at relatively low levels in the Caloosahatchee River. During the dry season, cool winter temperatures counteract the effects of higher, more favorable, salinity due to low freshwater inflow. During the wet season, lower salinity, due to rainfall and runoff, counteract the effect of higher more favorable temperatures.

Volety and Tolley (**Appendix B**) compared the response of oysters to infection by *P. marinus* during the dry season of 2001 (drought conditions) and during the dry season of 2002 when freshwater inflows were higher due to releases from Lake Okeechobee. Daily discharge at S-79 during the dry season of 2001 (Nov 1, 2000 – May 30, 2001) averaged

73 cfs. During the dry season of 2002, discharge averaged 460 cfs. While temperatures were similar at all sites during the two dry seasons, salinities were lower during all months of the dry season of 2002 at Piney Point, Cattle Dock, and Bird Island. Depending on site and month, differences ranged between 1 and 14 ppt. At Kitchell Key salinities were lower only during the months of January through April (Appendix B).

While infections were light during both years, the rate of infection was lower during the dry season of 2002 when low level releases of freshwater were made from Lake Okeechobee (**Figure 2-2** and **Figure 2-3**).

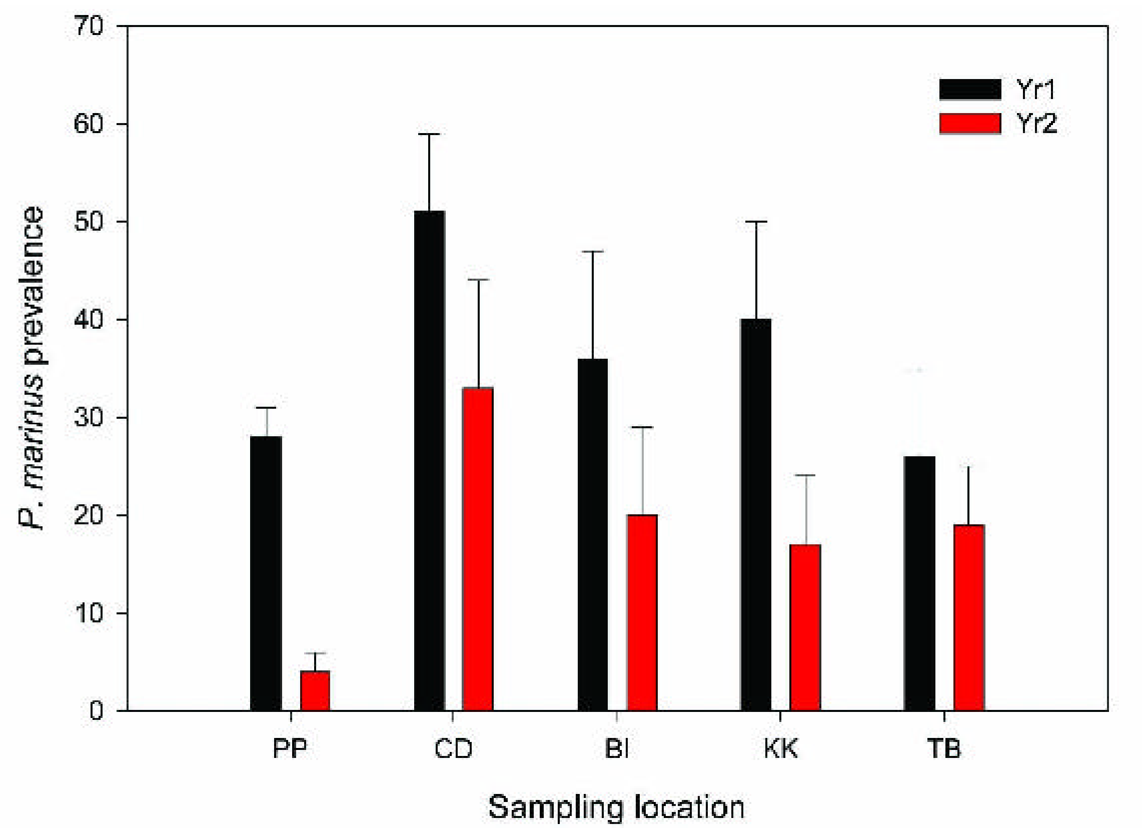

Figure 2-2. Mean *P. marinus* prevalence (± SE) during winter months in oysters from Piney Point (PP), Cattle Dock (CD), Bird Island (BI), Kitchel Key (KK), and Tarpon Bay (TB) in Caloosahatchee River (see **Figure 2-1** for locations) during years 1 and 2. November – May were considered as dry months due to paucity of rainfall. Years 1 and 2 are from September 2000–August 2001, and from September 2001–Present, respectively. Ten oysters were randomly sampled from each location per month and prevalence of *P. marinus* in oysters was analyzed according to Ray 1954. Increased freshwater releases from Lake Okeechobee and resulting decreased salinities were associated with lower infection intensities in oysters from all of these locations.

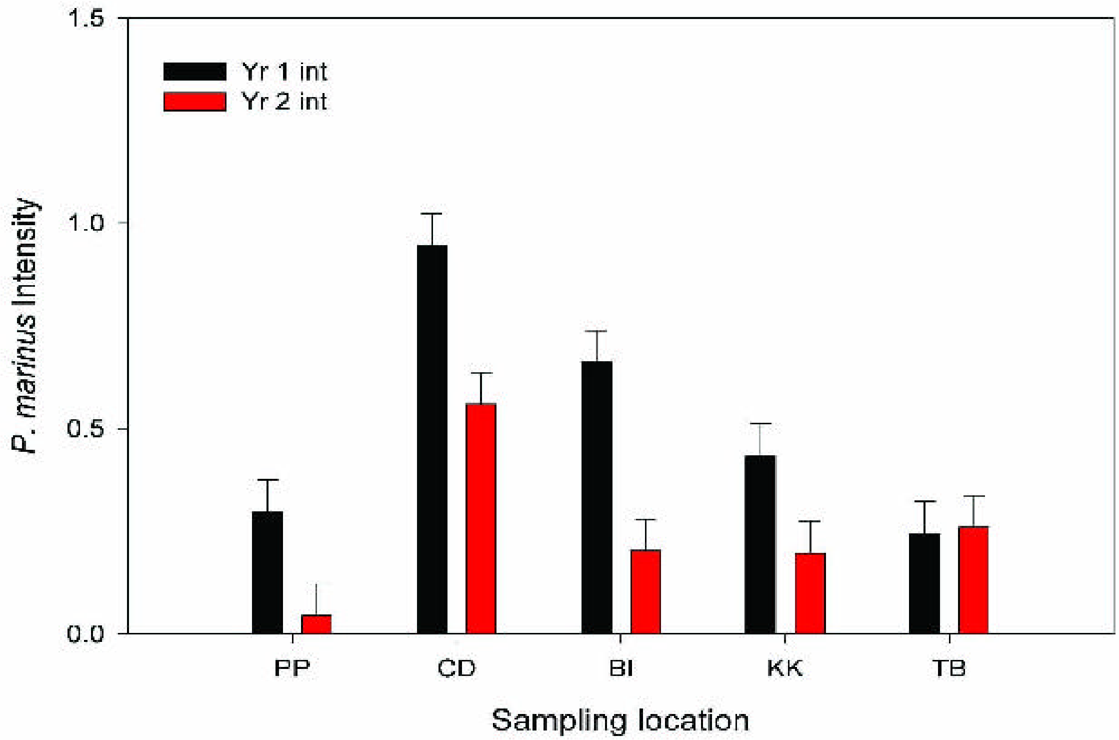

Figure 2-3. Mean *P. marinus* intensity (± SE) during winter months in oysters from Piney Point (PP), Cattle Dock (CD), Bird Island (BI), Kitchel Key (KK), and Tarpon Bay (TB) in Caloosahatchee River (see **Figure 2-1** for locations) during years 1 and 2. November – May were considered as dry months due to paucity of rainfall. Years 1 and 2 are from September 2000–August 2001, and from September 2001–Present, respectively. Ten oysters were randomly sampled from each location per month and intensity (Int) of *P. marinus* (weighted incidence) was analyzed according to Ray 1954. Increased freshwater releases from Lake Okeechobee and resulting decreased salinities were associated with lower infection intensities in oysters located upstream of Tarpon Bay.

These results suggest that low level releases may be beneficial. However, because infections were light and non-lethal, the results also suggest that flows less than 300 cfs during the dry season do not cause "significant harm" as measured by *P. marinus* infection. However, the current study did not examine mortality caused by marine predators that may be present during periods of high salinity.

Given that optimum salinity for oysters ranges from 10 to 28 ppt (Sellers and Stanley 1984), under the prevailing salinity regimes, high flows exceeding 3000 cfs, may cause severe mortality and low larval settlement. Based on a regression model (Volety and Tolley, **Appendix B**), flows between 500 cfs and 2000 cfs would result in salinities of 16–28 ppt in the region between Piney Point, in the Caloosahatchee River and Kitchell Key, in San Carlos Bay. According to the regression model (Volety and Tolley,

Appendix B), a flow of 300 cfs would keep salinity within the optimum range at Piney Point and Cattle Dock. Under current water management practices, oysters in the Caloosahatchee River are not stressed by low flows (less than 300 cfs), but are stressed when high flows exceed 3000 cfs for extended periods (2–4 weeks, **Appendix B**).

Phytoplankton

The District has monitored chlorophyll *a* as a measure of phytoplankton biomass in the Caloosahatchee Estuary, San Carlos Bay and Pine Island Sound under a range of freshwater discharge conditions at S-79 (Doering and Chamberlain 1998). Monitoring was not continuous but occurred on a monthly basis during periods from 1986 to 1989 and 1994 to 1995. Detailed results are presented in Doering and Chamberlain (1998).

Figure 2-4 shows a typical longitudinal distribution of chlorophyll *a*, with a distinct maximum in the upper part of the estuary just downstream of Beautiful Island. Highest concentrations of Chlorophyll *a* tended to occur most frequently in the upper Caloosahatchee Estuary and less often in San Carlos Bay and Pine Island Sound (see **Figure 2-5** for locations). In part, this pattern seems to be related to freshwater discharges at S-79. The statistically significant ($P<.02$) linear regressions shown in the bottom two panels of **Figure 2-4** demonstrate that both the magnitude of this maximum, and its location in the estuary are, in part, functions of discharge (Doering and Chamberlain 1998). Visual comparison of open circles (wet season, Jun 1– Oct 31) and closed circles (dry season, Nov 1– May 30) suggest that the relationships do not vary seasonally. While other factors such as light, temperature, nutrients and grazing influence the distribution and abundance of phytoplankton, the influence of freshwater discharge on the distribution of plankton in estuaries is a well documented phenomenon (Welch et al. 1972; Fisher et al. 1988; Doering et al. 1994).

These results suggest that large blooms, which may cause water quality problems such as reduced light penetration or low dissolved oxygen concentrations, can occur in the upper estuary over *Vallisneria* beds. In fact, relative to the rest of the southern Charlotte Harbor system, the upper Caloosahatchee Estuary exhibits the highest chlorophyll *a* concentrations and lowest dissolved oxygen concentrations in bottom waters (Doering and Chamberlain, 1998).

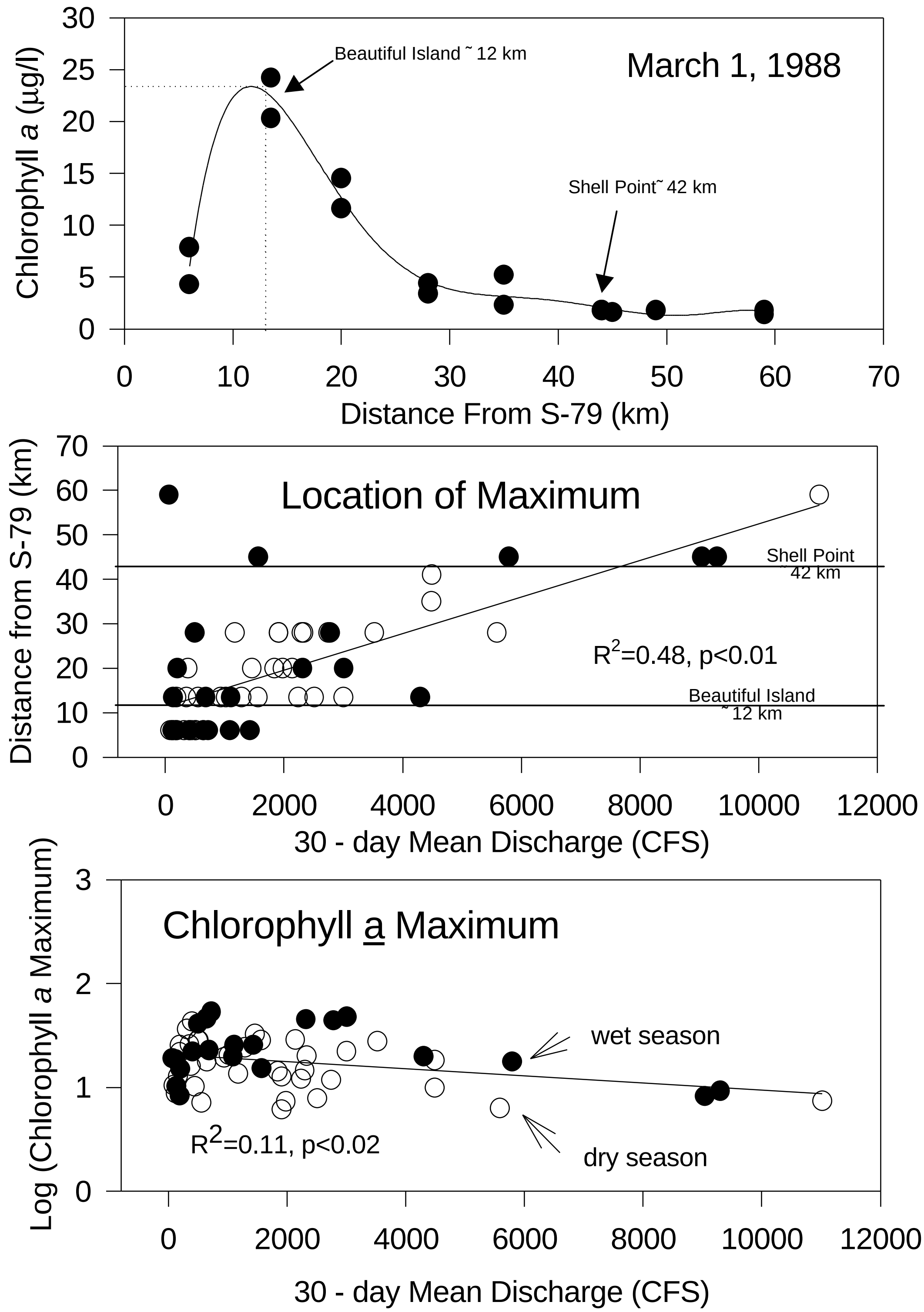

Figure 2-4. Chlorophyll a in the southern Charlotte Harbor system (0 km at S-79, 60 km in Pine Island Sound). Top: Typical distribution showing position and magnitude of bloom. Middle: Discharge and magnitude of bloom. Lower: Discharge and location of bloom.

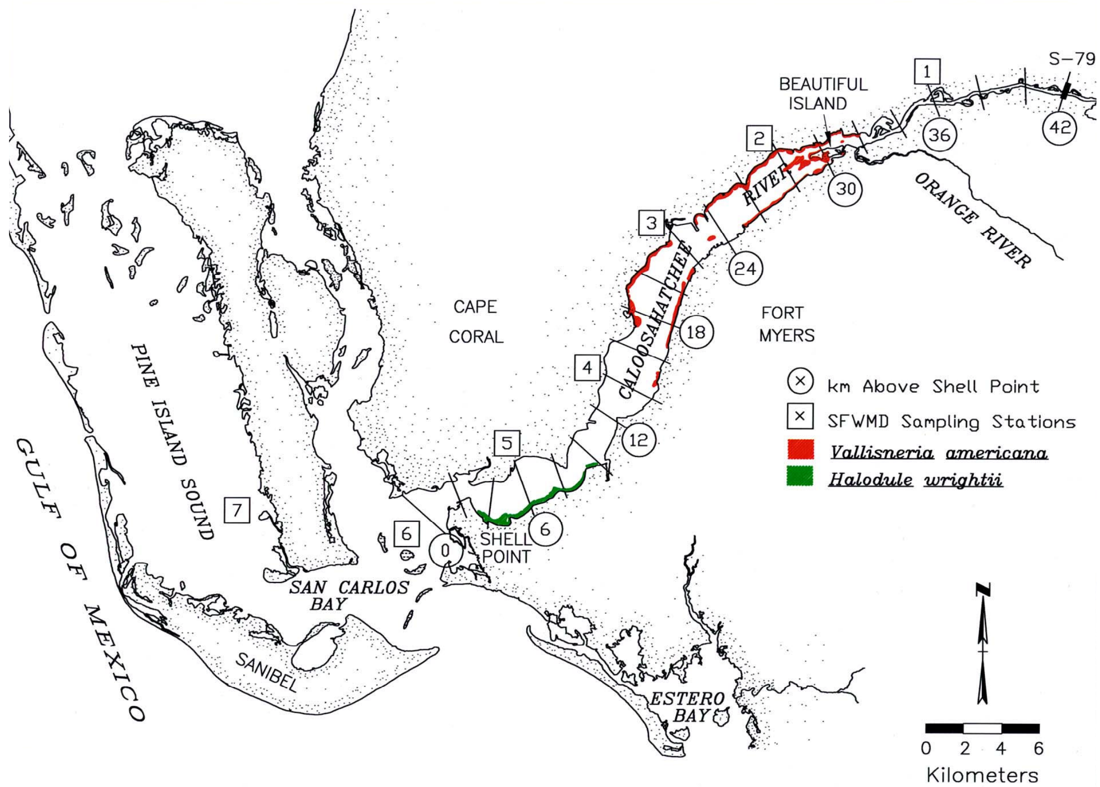

Figure 2-5. Location of sampling stations relative to locations of seagrasses within the Caloosahatchee Estuary.

Low flows can provide conditions that are favorable for phytoplankton blooms to occur in the upper estuary. These blooms, in turn can create water quality problems associated with decreased light penetration and night time oxygen levels as well as accumulation of metabolic wastes and plant toxins. The way in which low, MFL flows are delivered (pulse vs. constant) is important and deserves further attention.

Zooplankton and Ichthyoplankton

The District has monitored zooplankton and larval planktonic fish at 7 stations in the Caloosahatchee Estuary, San Carlos Bay and Pine Island Sound during various freshwater discharge conditions at S-79 (**Figure 2-5**). Monitoring was not continuous but occurred on a monthly basis during the following periods: 1986 to 1989, 1994 to 1995, and 1998 (**Appendix C**).

Mean zooplankton density increased along with salinity and distance from S-79. Zooplankton density was generally greatest during late spring to early summer and was lowest during August to November when rainfall tends to be highest. Low zooplankton abundance is associated with freshwater inflows and lower salinity regardless of the season. Zooplankton density was weakly related to salinity, but correlated well with freshwater inflow volume, possibly due to a "wash out" effect.

Although the mechanism is unknown, some freshwater inflow to the estuary appears to be necessary for zooplankton to achieve maximum density. Moderate rates of freshwater inflow may provide nutrients that stimulate production of phytoplankton, which in turn provide food for zooplankton. In the Caloosahatchee Estuary (Stations 1 to 5 on **Figure 2-5**), the greatest densities of zooplankton were measured when inflows were 150 to 600 cfs. At flows between 0 and 150 cfs, densities declined. Inflows that exceed 1,200 to 1,500 cfs were associated with reduced zooplankton density. Inflows that were greater than 2,500 to 3,000 cfs supported the lowest density (**Figure 2-6**). In San Carlos Bay (Station 6) and Pine Island Sound (Station 7) no relationship between discharge at S-79 and zooplankton density was detected (**Figure 2-6**).

Ninety percent of the shrimp and crab larvae were collected in the lower Caloosahatchee Estuary (Station 5 at Iona Cove) and in San Carlos Bay (Station 6). Peak abundance occurred in San Carlos Bay when salinity exceeded 20 to 25 ppt. Thus, inflows that do not exceed 2,500 to 3,000 cfs will protect the San Carlos Bay spawning and rearing area. Inflows below 1,200 to 1,500 cfs will also provide habitat upstream of Shell Point.

Freshwater inflows < 600 cfs were associated with the highest ichthyoplankton and egg density in the Caloosahatchee Estuary (Stations 2 to 5, **Appendix C**). The maximum ichthyoplankton use of the estuary and spawning occurred in most areas during low flows. Ichthyoplankton and eggs were greatest during the dry season, especially in spring (March-June). Dry season and spring minimum inflows necessary to protect upstream SAV will not adversely impact ichthyoplankton and egg abundance. Inflows < 600 to 800 cfs, associated with higher seagrass production near Station 5 (Doering et al. 2002), should also maximize ichthyoplankton and egg abundance in this region and downstream.

Marine Seagrasses

The marine seagrasses, *Halodule wrightii* and *Thalassia testudinum* occur in the lower Caloosahatchee Estuary (*H. wrightii*) and San Carlos Bay (*H. wrightii, T. testudinum*) (**Figure 2-5**). Laboratory experiments indicate that *H. wrightii* can survive salinities

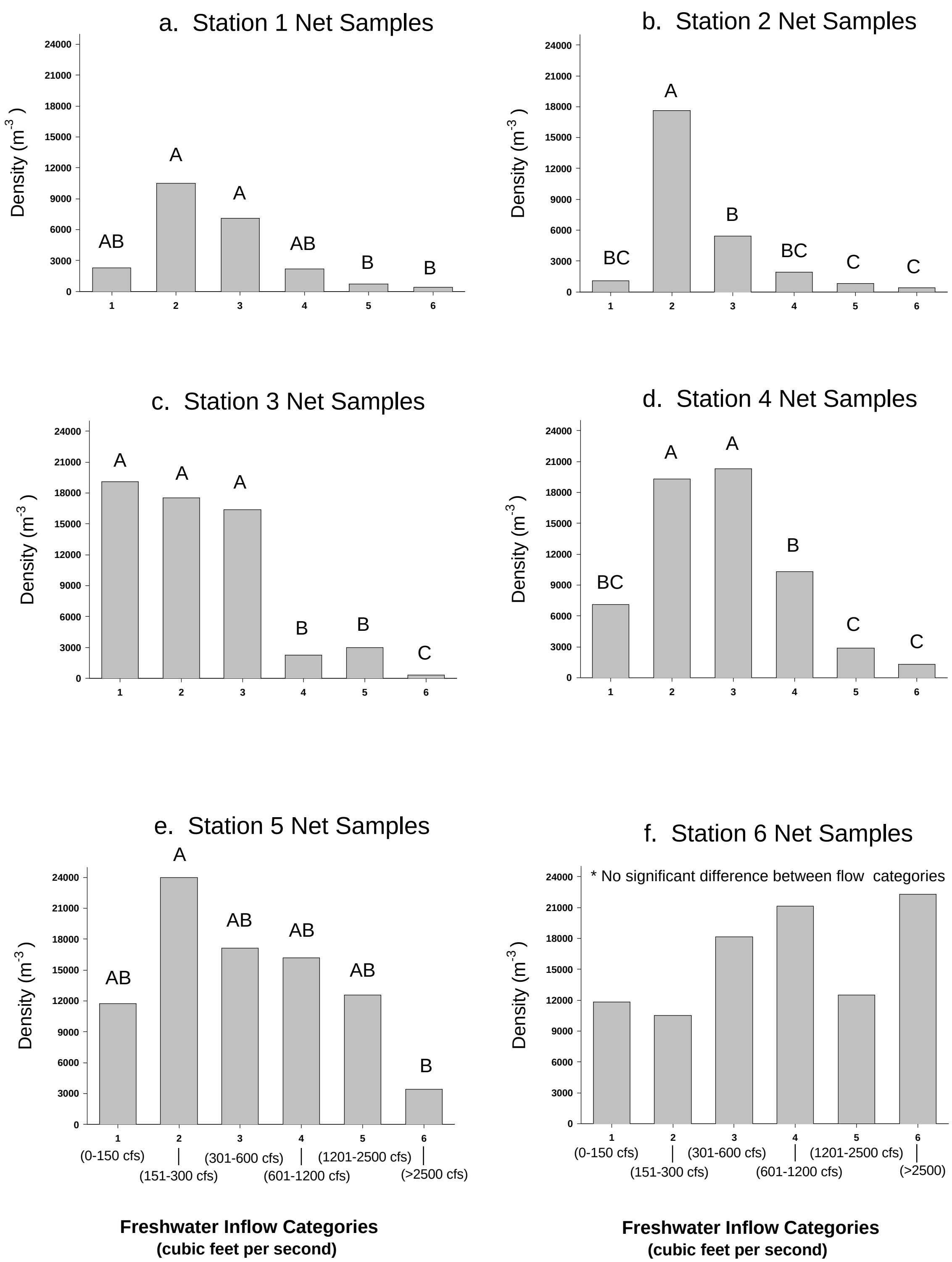

Figure 2-6. Effect of freshwater inflow at S-79 on net collected zooplankton density, sampled monthly at six downstream stations. Bars with different letters are significantly different ($p<0.05$).

greater than 6 ppt. Field data indicates that highest densities occur above 20 ppt (Doering et al. 2002). Likewise highest densities of *T. testudinum* occur in the field at salinities greater than 20 ppt. In the laboratory, *T. testudinum* has been shown to survive a six week exposure to 6 ppt (Doering and Chamberlain 2000). Discharges of over 2800 cfs at S-79 are required to lower salinity to 6 ppt in the lower estuary (Doering et al 2002). Flows of 300 cfs will not lower salinity sufficiently to impact marine seagrasses in the lower estuary or in San Carlos Bay (Chamberlain and Doering 1998).

In summary, low flows of about 300 cfs at S-79 do not appear to have detrimental effects on zooplankton, ichthyoplankton or oysters. This result suggests that the flows that benefit *V. americana* in the upper estuary are not detrimental to other organisms that utilize the estuary. In fact, low flows (<600 cfs at S-79) correlate with higher abundances of ichthyoplankton and zooplankton in the upper estuary. These flows may favor spatial overlap between ichthyoplankton and their zooplankton food source. Low flows at S-79 also correlate with the occurrence of phytoplankton blooms in the upper estuary. While blooms may serve as a food source for zooplankton, if unchecked by grazing, they can lead to water quality problems such as depressed oxygen levels. Oysters in the lower estuary do not appear harmed by low flows and may benefit through a reduction of the intensity of infection by *Perkinsus marinus*. **Table 2-1** summarizes relationships between various organisms and discharge at S-79. Low flows in the 300 cfs range are not harmful whereas flows greater than 2500–3000 cfs appear detrimental. This high flow limit agrees with previous estimates (Chamberlain and Doering 1998; Doering et al. 2002).

Table 2-1 . Summary of relationships between various groups of organisms and freshwater discharge at S-79.

Organism	Area	Flows at S-79 (cfs)		
		Not Harmful	**Optimal**	**Detrimental**
Oysters	Estuary –San Carlos Bay	300 - 500	500 – 2,000	> 3,000
Zooplankton	Estuary	----	150 - 600	>2,500 – 3,000
Shrimp & Crab Larvae	San Carlos Bay	----	< 2,500	> 2,500 – 3,000
Shrimp & Crab Larvae	Estuary (Iona Cove)	----	< 1,200	>1,500
Ichthyoplankton	Upper Estuary	----	< 600	----
	Estuary (Iona Cove)	----	600 – 800	----
Halodule	Estuary (Iona Cove)	----	<800	>2800
Halodule, Thalassia	San Carlos Bay	----	<800	>4500